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Interface Concepts for Command & Control Tasks

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Summary
This paper addresses new interface concepts for information visualisation and manipulation in Command and Control. These concepts focus on the use of multiple views on the tactical situation to enhance situational awareness and to improve situation assessment. Topics covered include the application of 3D perspective and stereoscopic displays.

INTRODUCTION

With command and control operations becoming increasingly more complex, there is a growing need for research on and development of effective command support tools. Probably due to the strong emphasis on information and technology, but certainly due to shortcomings in our present understanding of command and control tasks, and the human capabilities they call on, many of today's command and control systems are more designed from an information system perspective than from a command support perspective.

To get a better understanding of tasks and needs for support, the analysis of tasks and the identification of critical performance shaping factors in the CIC have been subject of several studies for the RNethN. What can be learned from these studies is the need for better tools to support situational awareness and situation assessment.

Easy access to information needed for these processes of awareness and assessment strongly depends on how the environment, situation, plans and system states are visualised and the way these views can be manipulated. Started as monochrome representations of raw radar and sonar data, the present-day tactical picture has developed into full-colour, computer-generated graphical representations of tracks (figure 1), serving as a basis for the presentation and flexible manipulation of different kinds of tactical and geographical information. Within this scope some new interface concepts for information visualisation and manipulation will be

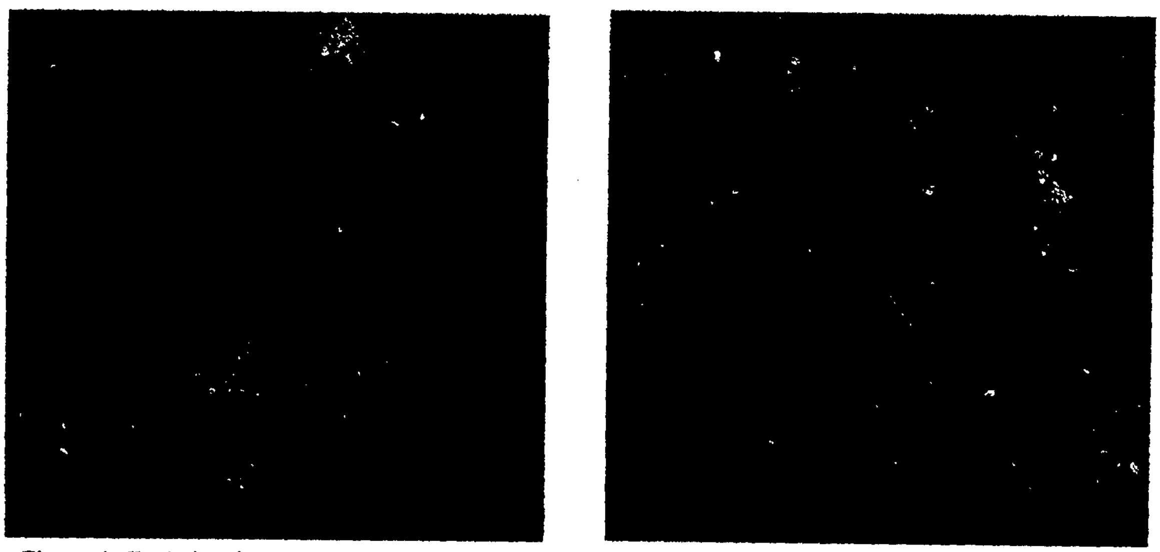

Figure 1: Evolution from monochrome vector display technology to present-day, full-colour raster-scan or flat-panel display technology. As a result of these developments, more possibilities for the presentation and manipulation of tactical data are offered.

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discussed. These include the use of multiple windows and (a.o. '3D') views on the tactical situation to enhance situation awareness, and the application of transparent information layers for an integrated presentation format. Results of experiments with the concept of multiple views indicate that higher information transfer rates could be obtained, together with a large decrease of required user interaction with the system. Finally, as an extension of the principles described here, the concept of tactical objects is introduced. This concept enables the user to modify and reconfigure the tactical workstation for effective supervision of and a rapid response to the tactical situation at hand.

Although the proposed concepts certainly need further testing and development for successful application, it will be concluded that they offer a promising perspective for the development of future information and task management tools.

MULTIPLE WINDOWS

In current command information systems and combat direction systems, information on the environment is mostly presented in a single, two-dimensional 'bird's-eye view', commonly denoted as the tactical picture. Inherent to this single-view presentation type, is the constant need to zoom in or out and to pan horizontally or vertically to keep the right focus on the tactical situation. Larger scale or longer distance views have to provide the necessary overview, smaller scale or short distance views the detailed information. In many cases it is hard to get both objectives combined in one unique setting of the tactical display. Larger scale or longer range settings often produce clutter or cannot offer information in enough detail. Smaller scale or shorter range settings required for the detail often do not offer enough context for a more global view of the tactical situation, and entail the danger to be 'taken by surprise' where relevant information stays out of sight. Switching between different display settings takes time. Not merely because of operator actions needed, or because of system response times, but above all because of the inevitable re-orientation on what is displayed when settings are changed. A situation in which sudden transitions can cause, as indicated by Woods [1], a loss of visual momentum. As a consequence, when under time pressure, operators may become reluctant to change settings, even if the way information is displayed does not suite the current situation.

Within this scope a study was performed on

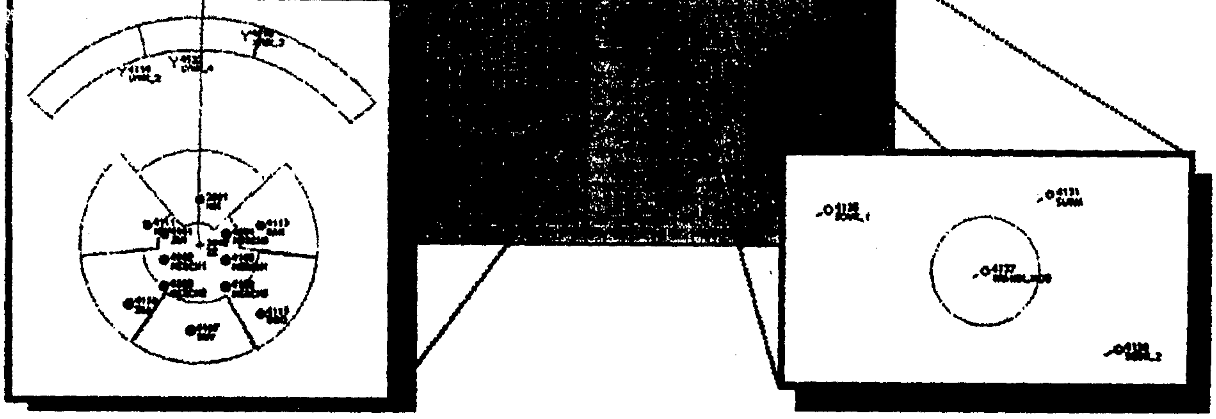

Figure 2: Example for the application of the multiple-window principle with operator selected parts of the tactical picture presented in separate windows for close monitoring. Every window has its own tools for filtering, display settings, positioning and sizing of windows. Separate windows can be temporarily 'closed' through minimising to icons presented on the overview display.

possible techniques to enhance the presentation of tactical situations [2]. The prime research goal for this study was the support of warfare officers in their situation awareness through parallel presentation of multiple windows on the tactical situation at hand, and flexibility in display configurations to support a situation dependent, optimised presentation.
The technique of multiple windows enables the operator to monitor different parts of the tactical environment in a parallel way and at different levels of detail (see figure 2).

In the experimental set-up as tested, operators had a tool at their disposal to select parts of the tactical picture (the overview window) for presentation in separate, additional windows. These windows have their own tools for filtering, display settings, positioning and sizing of windows. The windows can be temporarily 'closed' through minimising to icons presented on the overview display.
It was expected that the use of multiple windows would have a positive effect on the alertness of operators with respect to changes in the environment. To test this expectation, eight warfare officers took part in an experiment in which performance in terms of information transferred and effort needed was measured for both a conventional 'single window' set-up (SW) and an experimental 'multiple window' set-up (MW). Subjects were asked for two different Anti Air Warfare and Anti Submarine Warfare scenarios, while monitoring the tactical situation, to detect and indicate as fast as possible changes in track behaviour, like course and speed, and other state variables.
Changes to be detected in these scenarios could be short-lived, representing the upper part of the transition frequency domain, or more lasting in different degrees, representing the lower part of the transition frequency domain. For the different parts in this frequency domain information transfer was measured in terms of detected changes relative to changes present in the scenario. For the analysis these changes could be weighed according to tactical relevance.
In figure 3 the information transfer function of tactically very relevant transitions ('high-priority targets') is presented for the multiple and the single window interface.
The results show that, given enough time (low transition frequency), nearly all 'high priority' transitions are detected and the information transferred approaches the maximum value of 1. This holds true for both the single and multiple

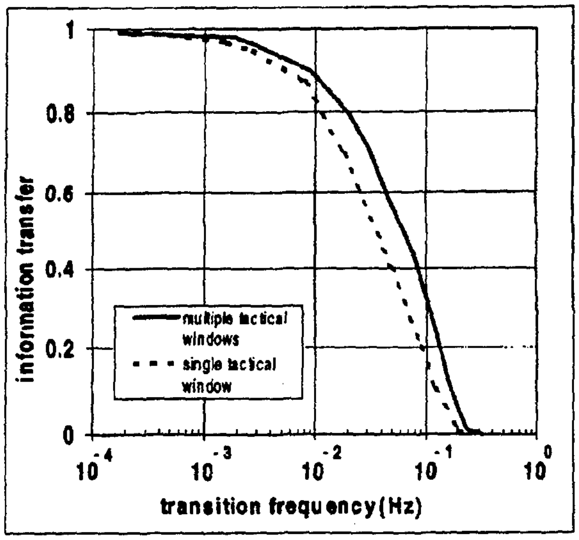

Figure 3: Amount of information transferred to the operator in multiple and single window conditions, as a function of the transition frequency. Low transition frequencies on the left side correspond with longer lasting changes in the tactical situation, high transition frequencies on the right side with short-lived changes.

window set-up's. However, an analysis of variance (ANOVA) on the transient part of the information transfer (transition frequency about 0.1 Hz) showed a significantly higher information transfer for the multiple windows condition, compared to the single window condition. Furthermore, as a measure of effort, all switching actions related to changes in display settings were recorded. The results are represented in figure 4. An ANOVA showed this number to be significantly lower for the multiple-windows condition (150 for the MW condition, 263 for the SW condition). In this experiment no specific effects could be found related to warfare type (AAW en ASW).

Resuming, results of the experiment show that the use of multiple windows has a positive effect on the speed of detection for high-priority targets. Given the frequency with which changes took place in the scenarios, subjects had less time to pay attention to lower priority changes. For these changes it took the subjects much more time to detect them, if detected at all, and as a consequence differences between the single and multiple windows conditions became less pronounced.
As an indication of required effort at the interface level to achieve a certain detection performance, a substantial reduction of user actions is obtained for the multiple windows set-up. Evidently, for the

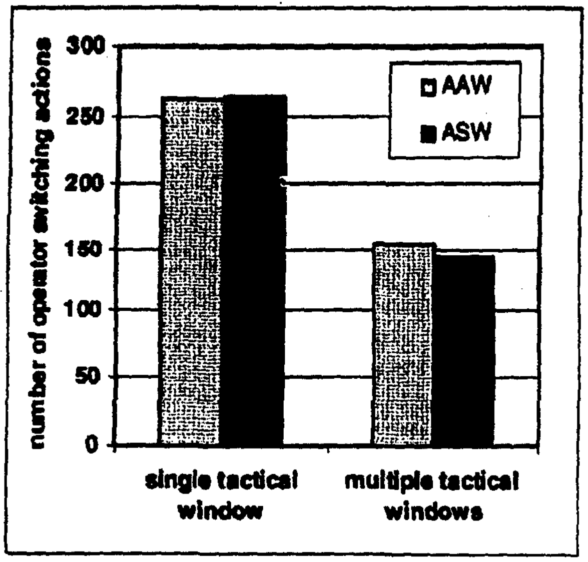

Figure 4: Number of operator actions related to changes in range selection and other display settings for two different scenario types (AAW vs. ASW), tested under single- and multiple-window conditions.

multiple-windows set-up subjects were better supported in tailoring the information presentation to the current tactical situation, resulting in less 'switching' effort required for this tuning process between interface and environment.

MULTIPLE VIEWS

As described in the previous section, information on the environment in current command information systems is presented in a two-dimensional 'bird's-eye view'. Regarded as much more effective than the older generation displays, new advances in graphics capabilities and display technology, however, may offer options for further improvement. In search for further integration, one of these options is certainly the application of 3D perspective or stereoscopic displays.

The strongest motive to go three-dimensional is the inability to combine the two dimensional 'bird's-eye view' with a graphical presentation of altitude and depth information. As a consequence, in all current systems altitude and depth information is presented as numerical read-outs. According to Dennehy et al. [3] representations lacking integrated altitude and attitude information complicate situation assessment in two ways. Data that are difficult to acquire, are more difficult to use in making a decision. Also, without immediately evident altitude information, a decision maker may substitute arbitrary or situation-biased altitudes, that may be difficult to supplant even when the actual data are presented.

With more realistic images of the environment and tracks in a 3D perspective, they argue, the interface becomes more natural and less effort is required to comprehend the current situation. It eliminates the

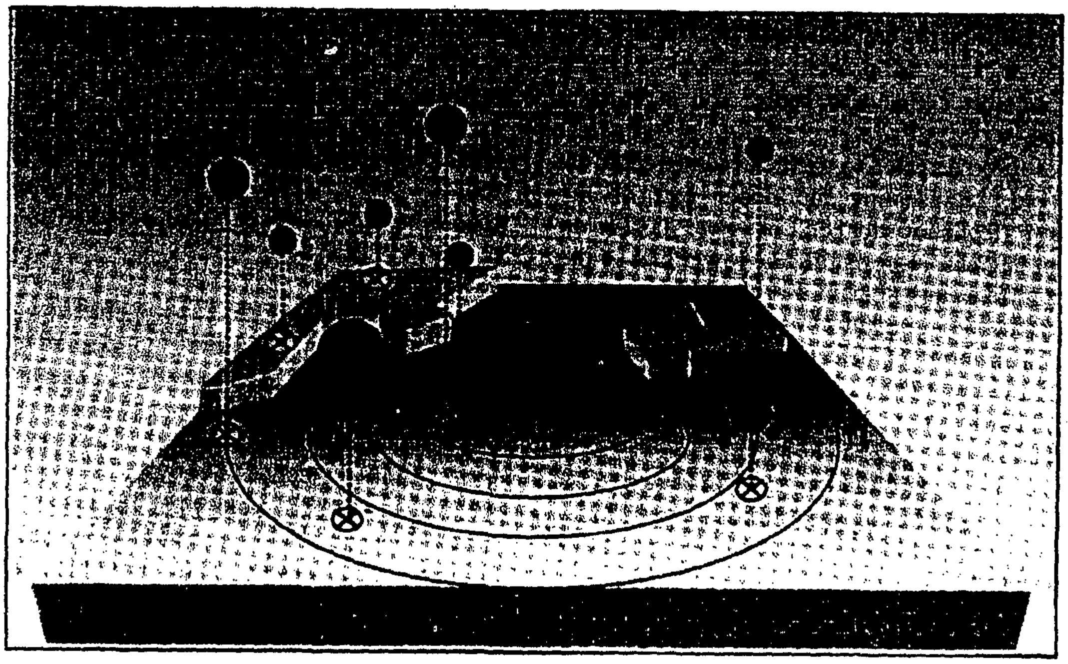

Figure 5: Example of simplified tactical picture presented on a 3D perspective display, with air tracks projected on the surface plane to amplify precise perception of position and altitude.

burden of integrating and interpreting of multiple representations, abstract symbols, and textual read-outs. Some earlier experimental results with perspective displays confirm these expectations. In a direct comparison between a conventional and a perspective display Bemis et al. [4] evaluated operator performance for two different types of tasks: detect threats and select the closest interceptor for each detected threat. The experiment revealed a significant reduction in errors of detection and interception with the use of a perspective display. Also response time for selecting interceptors was greatly reduced. Indicating the potential to improve performance, 3D perspective or stereoscopic displays, however, can also have their drawbacks. Inherent to the perspective view, objects are presented larger or smaller as a function of the operators viewing distance, location and angle. Objects close to the operator will be shown with much more resolution than objects at larger viewing distances. In many cases these differences will not necessarily reflect differences in tactical relevance and meaning.

One can also question how accurate altitude or depth

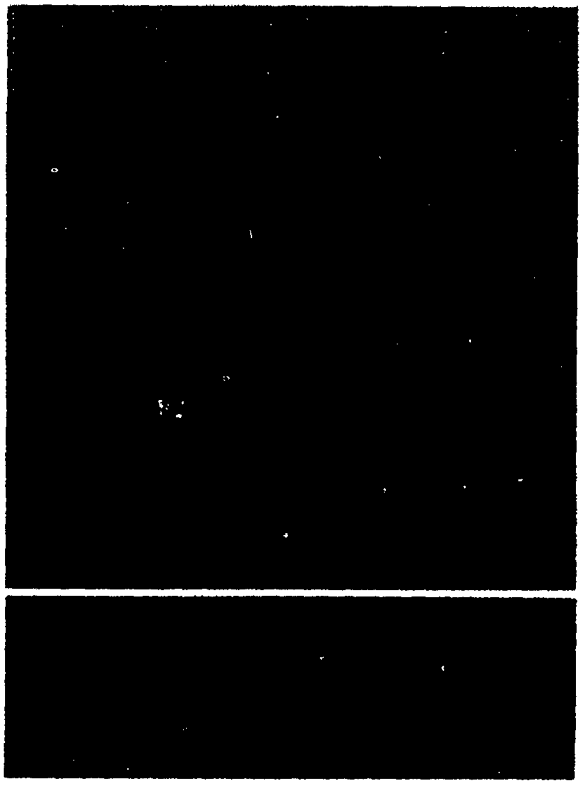

Figure 6: 3D perspective split-up in 2D view from above and side-view, as an example for what is defined as a multiple view display.

information can be perceived. To prevent errors, and to facilitate more precise altitude perception, extra visual cues have to be added like projections on the earth's surface and ruled vertical lines connecting the object symbol and the surface (see figure 5).

Furthermore, to resolve ambiguities and to reduce clutter, operators should have full control of viewing distance, angle and position [5]. Although this will give the operator the flexibility to visualise tactical data more freely it is not clear what effect frequent changes in view will have on orientation and situational awareness.

To study the last question in particular, an experiment was conducted to test how solid or reliable the internal representation of a tactical situation is when the situation has been extensively explored from different viewing locations [6]. Air and surface objects in the explored situation were moved, removed or interchanged position. Some changes were easy to recognise, others more subtle. Shots of the changed situations were put together with shots of the situation as explored, and subjects were asked to judge every shot on whether the situation was changed or not. Performance for a 3D stereoscopic display was compared with a 2D multiple-view display. This 2D multiple view was a composite display, with a side-view added to the conventional bird's-eye view (see figure 6). It lacks the integration of the 3D display, but has the advantage of a graphical representation of altitude or depth, without the drawback of perspective distortions.

Results of the experiment show that performance was not as naturally in favour of an integrated 3D display. Subjects in the 2D multiple-view condition had a significant higher score on correct identified shots, being the tactical situation as explored or a situation that had changed (see figure 7).

Analysis of data from a second experiment, to be reported this year, show, in addition to this result, that differences in sensitivity to changes especially hold true for the small, more subtle changes. Regarding response time, the time needed to identify a tactical situation as unchanged (same) or changed (different), responses for the 2D multiple-view condition had the tendency to be a little bit slower, but the difference was too small to be statistically significant.

Although more experiments are needed with more tasks to be tested, the results put some doubts on explanations that performance improvements as found in earlier experiments largely depend on integration in a 3D perspective display. An even better performance was found with related, but non-integrated multiple views of the tactical situation.

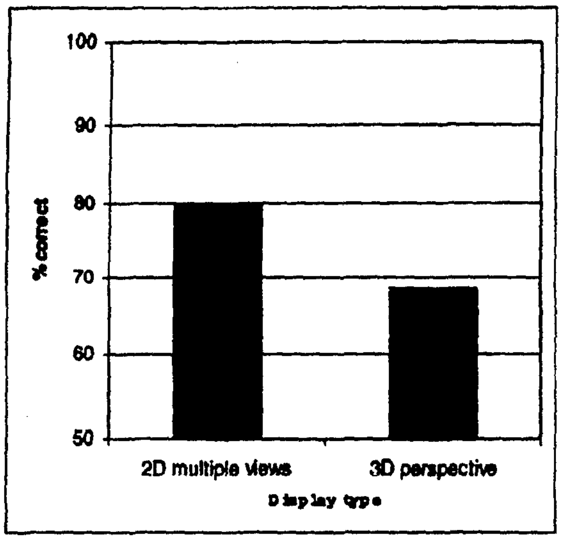

Figure 7: Percentage of correct same-different answers to questions testing the operator's sensitivity to changes in the tactical situation. Scores are presented as deviations from the 50 % baseline, associated with completely random, non-sensitive operator behaviour.

The change from numerical read-outs to the graphical representation of altitude or depth seems to be the most important one to realise a more effective information transfer and an improved situational awareness. With integration no further improvements were obtained. Disadvantages of perspective views even seem to have a suppressing effect on performance accuracy.

MULTIPLE LAYERS

The most obvious application of 3D stereoscopic displays is to get an almost 'natural' representation of objects in the battlespace, as described in the previous paragraph. Stereoscopic vision, however, can also be applied for the visual separation of different information layers with each layer containing two-dimensional representations.

With the transition from vector displays to raster-scan displays and flat-panel displays in the near future, together with fast powerful graphics processing, the potential for all kinds of graphical representations of information has strongly expanded. As a result, many categories of information can be brought together in one integrated graphical representation of the environment and the tactical situation.

To prevent problems like display cluttering or visual interference and to optimise the tactical picture for the task or the situation at hand, new generation systems offer extensive filter and display options. In practice however, operators show reluctance to use the flexibility offered where too many options have a negative impact on overview and accessability, and extensive interaction with the system is required, especially under time pressure.

Another way to cope with this problem is to search for well-balanced visual representations in which the perception of objects like air or surface tracks does not interfere with the perception of supporting graphical information in the background. Some new opportunities to accomplish a better visual seperation between foreground and background information became available with the introduction of full-colour displays.

An example of the difference between the classical monochrome tactical display and a full-colour tactical display was already given in the introduction (figure 1). This example of the full-colour tactical display reflects some of the information-presentation principles as applied to the tactical displays on board the M-class frigates of the RNethN. Through the combination of information presentation in both positive and negative contrast, a visual seperation could be realised between three different information layers:

- area filled geographic information in different shades of gray,
- primary track information in bright colours on the foreground in *negative contrast* with the display background,
- and supporting, secundary information in dark colours on the foreground in *positive contrast* with the display background.

Although regarded as a significant improvement, the possibilities remain limited and do not allow to expand to a more full-scale multiple-layer model for the organisation and integrated presentation of information as presented in figure 8. Experiments with stereoscopic displays reported in the previous paragraph, however, triggered the idea to present the information layers at separate viewing distances. It will allow the operator to visually focus on one layer in the context of information in other layers.

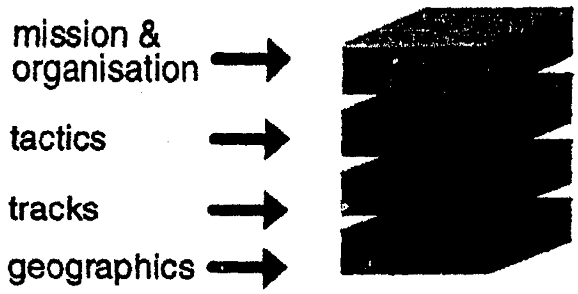

Figure 8: Multiple layer concept for the organisation and integrated presentation of information.

What the impact will be on performance in terms of situational awareness, assessment and decision making is still unknown. Many research questions have to be answered. As part of a research program on emerging interface technologies and their application in command and control, preparations have been started to build a concept demonstrator, to have the tools to test and evaluate the potential of such a tactical display.

TACTICAL OBJECTS

Besides the increasing amount of available information, present-day combat management systems offer a large variety of functions and services, possibly set up in a flexible way for the tuning of this functionality to the different operator roles. However, a possible negative side-effect in this approach may be the rather diverse ways in which the required information for important tasks such as threat evaluation, assignment of sensor/ weapon systems, and weapon deployment, is divided over different system services. Thus, it requires a certain amount of mental effort to maintain overview of the 'flow of information', system settings, filters etc. This problem may be enlarged by the variety of functions and services which are available through various (a.o. soft-key type) input devices, with a lack of context sensitivity.

Within this scope, possibilities for innovation currently are under study, exploring the way in which functions may be represented and organised in future tactical workstations. Based on the 'select then operate' principle, system effectiveness possibly may be increased by considering the tactical display not only to be an output medium for the presentation of tactical data but also an input medium for the selection and activation of functions. The envisioned outcome of this study is an object-oriented interface design, enabling the user by direct manipulation of 'tactical objects' on the tactical display to modify and reconfigure the tactical workstation for an effective supervision of, and rapid response to the tactical situation at hand.

DISCUSSION AND CONCLUSIONS

Within the next generation combat information centre, command teams will have to interact with complex information processing systems. Data from many sources in large databases have to be selected, combined and manipulated. From a warfare officer's point of view, usability and accessibility are keywords of primary importance. Easy access strongly depends on how the environment, situation, plans and system states are visualised, and the way these views can be manipulated. New concepts and technologies for graphic information presentation and object manipulation, both two- and three-dimensional, already are or will become available

In this paper some new concepts have been introduced. The common denominator seems to be the word *multiple*: multiple windows, multiple views and multiple layers. They all reflect the problem of integrating growing information flows in one view or window known as the tactical picture.

Results of experiments indicate how the organisation of information in separate windows, views and layers can improve information transfer and situational awareness.

The way information is organised, however, also depends on the task and the tactical situation at hand. The next challenge is to develop a tool for easy re-organisation of information display when operators have to switch between tasks or when changes in the tactical situation take place. Development and testing of the tactical object as an organising principle is regarded as the first step to meet this challenge.

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